Information and Computer Science

THE ROLE OF COMPUTERS IN MASTERY-BASED COURSES

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One of the interesting educational developments in the past few years has been the rise of a new method of structuring courses, emphasizing that the students should master <u>each</u> topic in the course. These courses usually offer students greater flexibility with regard to their rate of progress through these courses. Variants of this system are called The Keller Plan, Personalized System of Instruction (PSI), and mastery learning. Although these methods are not a panacea, they offer interesting new possibilities for organizing courses, while also presenting new types of problems.

The purpose of the present paper is to review the roles of the computer as a learning device in mastery courses. I argue that the computer has some unique capabilities for assisting in such courses. Illustrations will be drawn from projects of the Educational Technology Center, undertaken with the assistance of the National Science Foundation and the Fund for the Improvement of Post-Secondary Education.

Mastery Courses

As the notion of a mastery course may not be known to all readers, and as this term is used in quite a variety of ways, I begin by giving some possible dimensions of such a course.

A mastery course is typically structured into a set of units; in the most common form, each unit is equivalent to about one week of work in a standard course. The emphasis is on learning each units, rather than teaching. The responsibility for learning is with students. They are given a careful description, unit by unit, of just what they are supposed to learn; a variety of learning materials is provided or identified for assistance in meeting the learning objectives for each unit.

Proficiency is demonstrated by unit tests, often taken several times until an almost perfect performance is achieved. The term "mastery" derived from this requirement of perfect performance. Several different forms of the test are available. The number of times a quiz is taken usually has no effect on the student grade. The emphasis is on full learning, rather than how long it takes.

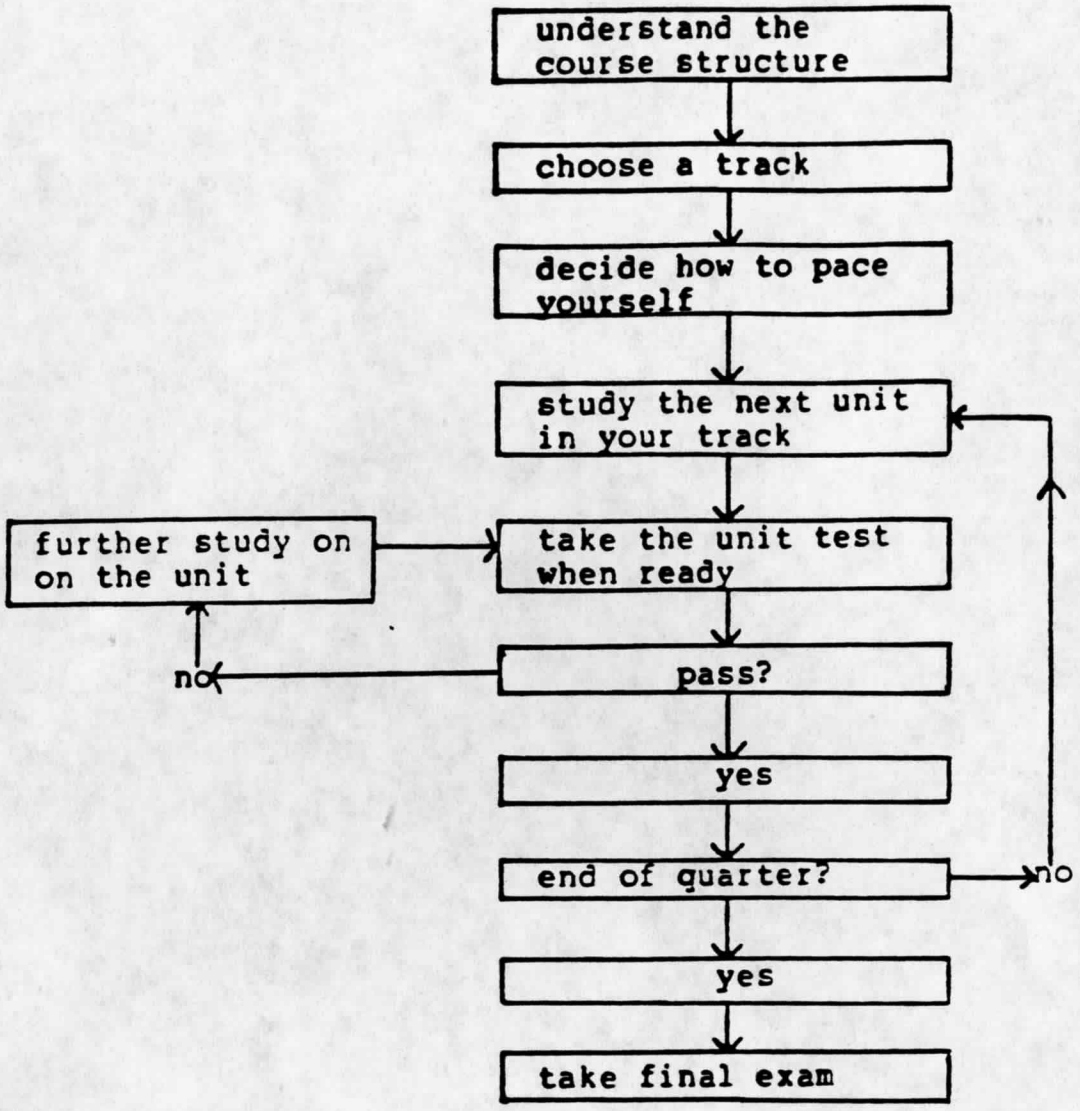
The students, possibly with some restrictions imposed by the teacher or by the institution, move through the individual units of the course at their own pace. Complete freedom in student pacing is seldom allowed, and has been disastrous in some cases in conventional academic environments, although it might work outside those environments.

Tutorial help, undergraduates or teaching assistants or

sometimes faculty, is often provided. These same tutors are often responsible for giving the unit tests and providing immediate feedback to students about specific difficulties on the tests. But, as I will indicate, this can be a computer role. Such courses are typically not lecture-based, although in some variants lectures are given for certain purposes.

As indicated, many variants exist. Almost every course has its unique features. The above description would probably not satisfy a purist. The emphasis, as already indicated, is on "mastery." This means that the students do not go into another unit until they have completely mastered a previous unit. Although the concept is important, this term is perhaps a little pretentious.[1]

The following diagram for students illustrates a possible structure for such a course.



Computers in Learning

Computers have been used in learning environments at an increasing level during the past fifteen years. We are amateurs at effective use of the computer in aiding learning, but we are becoming more skilled. Student access to computers is increasing rapidly, at all levels. This computer movement in education has

been independent of interest in mastery courses, and has had little overlap with the ideas described in the first section. A variety of computer modes is possible to enhance such courses, and should not be overlooked in any full consideration of the role of the computer in education.[2]

The computer when used in an interactive mode, with the student engaging in a "conversation," a dialog, written by competent instructors, is a one-to-one or, better, a one-on-few learning device. If the student-computer dialog was written by a group of excellent teachers, it has some aspect of the student working individually with the teachers. The dialog can be very adaptable to the needs of individual students, giving help where needed and going quickly over sections where the student demonstrates knowledge. Computer materials do not depend on physical supervision, or a particular scheduling situation. Computers may be available twenty-four hours a day, and so the materials will always be accessible to students.

Computers are good in keeping records. Each student's use can be recorded, so, as opposed to other learning environments, we know what extent students are using the resources provided within the course. Teachers can obtain, easily, detailed information on student activity and progress. Furthermore, extensive feedback for authors can be provided, enabling programs to be improved for successive classes. The computer can store the responses that could not be analyzed, and these could be used to make a substantial improvement in the interactive aspects of

the program with the intended student audience.

In the following sections, I look at specific examples of modes of computer use in mastery courses.

The Computer as Tutor

One role of the computer in learning involves situations where students engage in an interactive dialog; the computer takes over functions of a tutor, or of students' reading. Many courses are dependent on books or notes, for many students not an interactive environment. Students are often poor readers, not checking themselves as they go along. Often they do not understand the purpose of reading assignments. Thus, physics students assure instructors that they "understand" everything, but they are just unable to solve the problems! This "understanding" has little to do with the learning objectives for physics.

The computer as tutor can constantly query students, probing understanding at each step. Specialized assistance can be offered where needed. Computer dialogs can be used in other environments, but mastery courses represent one possibility.

A dialog which functions as a tutor, both in terms of helping the student learn the material and in providing a unit test is LUNA, written initially for use by elementary and high school teachers by Arnold Arons and Alfred Bork.[3] It develops an important concept, the notion of a scientific model, using the

phases of the moon as an example of a model. LUNA, like many of the Irvine dialogs, includes graphics, including graphic input. The quiz at the end is randomly selected from a large collection of questions; immediate assistance is given if the student does not do well on a question. Questions depend on being able to use the model stressed, that of the phases of the moon, to make other predictions.

Another type of self-contained unit is seen in other Irvine dialog materials. The example I describe is SPACE, with a Piaget-like structure. Three fundamental facilities are _____: An interactive spacetime diagram, a concept section, and a problem session.

The spacetime diagram provides a facility for students to gain a range of experience concerning the behavior of the relativistic world not attainable in the world of everyday experience or in the world of the physics lab.

The concepts part of the program allows formal learning in the usual sense Students can enter each of the concepts, a series of small learning units, and work interactively to understand the concepts, ideas, and relevant techniques. They may engage in a variety of activities, all interactive and all directed toward learning the concept.

In the problem section, students see whether they understand the material in the way understanding is typically tought in physics, by solving problems. These problems have additional teaching material available when students have not grasped the

necessary information or techniques from the concepts. The program knows what concepts the student has already studied and can make decisions in the problems based on that information. Some problems are based on problem generators, with unlimited variety available until students succeed with problems of that kind. Others are based on the spacetime facility, but now with the computer watching at each step what the student is doing, unlike its use in the free play sequences.

This program is characterized by learner control, students moving freely from one component to another. (But if students try to leave a concept before completion, we plead with them to finish it!) As with other self-contained, computer-based units described, the computer can do its own record keeping.

Unit Tests

The heart of any mastery based course are the unit tests. They enable students and teachers to determine whether students have mastered the material, and so they are most critical in any mastery course.

In a situation where computers are available for student use, the mastery unit tests can all be given directly from the computer, on-line. So they become the heart of the course. This procedure, on line testing, has a number of advantages. The test items can come primarily from problem generators, each capable of generating a wide range of questions; so items can be significantly different each time the test is given. It is also

possible to establish pools of questions, and to pick randomly from these. However, the results of question pools so far have been less satisfactory than generators, due to the difficulty of establishing a sizable enough pool of very high quality questions, and the difficulty of assuring that all questions in a pool test the same thing at the same level of difficulty. The two sources of questions, generators and pools, can also be combined.

Another major advantage on on-line tests is that the results of these tests can be directly stored by the computer. Record keeping is an important component of a mastery course. I will discuss later the issues of course management involved with on-line record keepers.

An on-line test can be a very different type of test than the typical paper and pencil test. First, the student can receive immediate feedback, as to correctness, on each problem, if desired. Usually reinforcement may be possible, even for correct answers. Furthermore, the student can, if it is desired, be told the correct answers to problems that are not handled correctly. The order of the problems, and the type of problems given can depend on the student performance. Exams can be stopped quickly if the student needs more help.

A major advantage of the on-line quiz is that the computer itself is doing the grading. We have found in running large mastery based courses that the manpower needed to grade conventional (noncomputer) quizzes is the major expense of such

courses. This type of expense is avoided with a computer, because the computer checks the student responses. Further, when many tutors are involved in grading, it is uneven, the computer is fair to all.

In the traditional quizzing with master based courses, the student, in principle, receives assistance immediately after taking the test, as the test is reviewed by a tutor; this tutorial aid is an important part of the course. But the quality of this tutoring can, in practice, vary enormously. Some tutors can be very responsive to human difficulties, others not.

With the computer it is also possible to give immediate assistance to students who are in difficulty. This assistance can be given after each problem, at the beginning of the test, at a few intermediate prints, or at the end of the test. That is, extensive and highly responsive help sequences can be built into the computer based test, using the best principles of computer based learning. These test sequences can use the results of the tests so far, based on analyzing student replies to the questions. Thus it is often possible to spot, for commonly recurring errors, exactly what difficulty a student has, and so to respond in an individualized way to that student's needs.

Unit Tests - Physics 5A

Perhaps the most elaborate implementation of on-line quizzes at the University of California, Irvine, was in connection with the Introductory quarter of a standard beginning physics course.

The materials developed were first used in a course used for nonmajors, and then later modified slightly for a course for majors in science and engineering.

On-line quizzes for the physics course, in addition to following all of the principles suggested in the previous section, also introduced one new idea. Far more quizzes were developed than were intended to be used by any one student. In fact, two complete courses for mechanics were developed, with quite different content. One of these courses was a traditional course, following closely the content usually followed in such courses not only in most universities in this country, but throughout the world. Thus it followed the standard textbooks. The second course was a radically different course, dependent also on use of the computer in programming modes. The student was involved in programming to learn components of physics. Notes were available to students for this alternate student track.[4] The 27 quizzes followed both of these modes.

The aim of this procedure was to allow students to have a choice with regard to the <u>content</u> in the course. In the different years that the course was given (the course was offered five different years) various strategies were used. In the early days, a number of crossovers were allowed, so that six paths through the material were possible. This amount of choice seemed a little bewildering to some students, so in the last few presentations of the course we allowed only two paths through the materials, the conventional one and the one involving student

programming.

The hallmark of the on-line tests in the physics course was the extensive student aid that they provided. The aid covered many of the expected difficulties, and was individualized to the student needs.

Indeed, the quizzes became, because of this extensive help, the major learning material of the course. That is, it is possible to go through the course taking only the quizzes. Student deficiencies were identified in the quiz, and very detailed and individualized aid was available. It was possible for students to learn the material using only the quizzes, because of this aid.

This is not to say that all students went through the course only taking on-line quizzes. Many students used the other learning materials available in this course, particularly textbooks and tutors, but students could go through the course taking only the quizzes. Each time the course was offered some students did proceed in this way. This type of course, which I like to call a "quiz driven course," is clearly possible only with the computer. It would seem to me to have many interesting ramifications for future mastery based courses, and for courses depending heavily on the computer.

Course Management

The mastery course looks more chaotic that the standard lecture course, because students at a given time are in different

parts of the courses, so they are studying a wide variety of materials. Hence, record keeping is an important aspect. The instructor needs to know who is behind, and therefore needs personal attention. At the end of the course, the teacher must obtain information for grades; in a large class we would like to do this in an efficient way that uses the capabilities of a computer.

The student, too, may have new problems in a mastery course. Students who missed the "introductory" session, or somehow were late in getting information, may be confused about their responsibilities. Students may want to know if they are making normal progress, and how that progress compares with that others are making. If actual grades are given on unit tests (a possible self-paced variant), they will want to know how their grades compare with those of others. In a multi-track course, where students have a number of content options at any given juncture, they would like information about available options.

These course management requirements can be satisfied through an on-line interactive database. Thus, the management aspects of a mastery course can be enhanced by the availability of computers. If the unit tests are given on line, suggested as a possibility above, the computer can enter directly in the database the information concerning the progress of the students.

Use of Media in Mastery courses

Previous sections have pointed out ways in which the

computer can be used effectively within mastery courses where students may have some control over progress through a course. Nevertheless, the use of the computer within such courses or, more generally, the use of any nonprint media, has been very small. The vast majority of Keller Plan courses taught have been based only on printed material.

I feel, in talking with many important figures in this movement, a definite resistance to media other than print media. This resistance is perhaps understandable in terms of films, as it is difficult to arrange an environment where films can be shown on demand.

These limitations with regard to films do not apply to computer material, which is always available to the student. I suspect that one limitation is that in many places the computer is simply <u>not available</u> for widespread usage with students, in the way indicated. In many schools the vast bulk of usage is for research, administration and the computer science courses. Personal computers will rapidly alter this situation.

But the major limitation is the lack of availability of good, well-tested, curriculum material supporting mastery-based courses. Books already exist, and so they can be adapted to the new learning modes involved. But we must create the necessary computer learning material for almost all course material. Effective development of curriculum material requires care and resources, with or without computers.[5]

As student available computer facilities become more and

more widespread in education environments around the world, and as better computer-based teaching material is generated, it seems reasonable that computers will play a major role in mastery courses, making those courses more available to a much wider audience.

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